GEORGE C. MARSHALL SPACE FLIGHT CENTER

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PROPERTIES OF THE F_2 REGION OF THE IONOSPHERE

by

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SUMMARY

The F_2 region of the ionosphere is considered to be that region of partially ionized gas whose peak varies from approximately 200 km to approximately 500 km in altitude depending on diurnal, seasonal, and other more anomalous variables.

A study of the F_2 region of the ionosphere has revealed areas of high electron concentrations. These areas will be of interest when considering ionospheric parameters which may influence spacecraft system designs. The IGY data (Ref. 1) available for the year 1958, have been studied and the areas of maximum electron densities have been given special attention in this paper. It should be noted here that the year 1958 was a year of maximum solar activity, which makes this an active year for the ionospheric perturbations.

The author wishes to thank Mr. Charles Dalton, Aeroballistics Division, Marshall Space Flight Center, for the considerable time he spent in reviewing this paper, and also for the many helpful discussions and suggestions.

SECTION I: INTRODUCTION

The F_2 layer of the ionosphere is being inspected by a study of the variations found in $f_o\ F_2$ for a wide range of latitudes. A proper representation of the peak of this ionospheric "layer" may reveal some of the driving and controlling mechanisms which influence the changes in electron concentrations.

Since this is a preliminary report to the work which will be continued, it does not contain explicit statements as to causes, but instead points out effects and in some cases suggests possible causes.

SECTION II: PROCEDURE

Data were considered from seventeen stations which, as identified in Table I, vary in geodetic latitude from 80°N to 90°S and in longitude from 65°18'W to 85°56'W. Within this longitude interval the geodetic latitude of the geomagnetic equator is within the interval from 6.5°S to 11.5°S.

When a radio beam is directed from a station toward the ionosphere, and the frequency is gradually increased, a critical frequency f_oF2 is reached, beyond which the beam is transmitted through the ionized layer. This frequency was found for each hour of the day and the values were averaged over a month's time for each station. These averages were then recorded on geodetic latitude versus hour diagrams. Contours of constant frequency were drawn by visual interpolation with respect to the recorded averages on the diagrams. The resulting contour maps are shown in Figures 1 through 4 for the months of March, July, September, and December, respectively. These contours of constant frequency are tentatively interpreted also to be contours of constant electron density (Section III).

In Figures 1 through 4 the pattern of the contours within approximately ± 20° from the geomagnetic equator differs significantly from that which one would have expected. In the polar regions, beginning at about 50° to 70° from either side of the equator, there is an apparent reversal in the gradient of the average critical frequency, which leads to considerable uncertainty in the construction of the contour patterns. This is due in part to the high absorption at the station at Trelew in the south and to the equipment uncertainties at the station at Clyde in the north. For this reason, the contour maps vary only from 60°S to 60°N latitude.

In Figures 5 through 8 the values of the average critical frequency are plotted against local standard time. Three latitudes indicated are those for: (1) Bogota, Colombia, $4^{o}32'N$, $74^{o}15'W$, (2) Tucuman, Argentina, $26^{o}53'S$, $65^{o}23'W$, and (3) an intermediate latitude near the geomagnetic equator.

The critical frequency f_oF_2 often increases after sunset. (Sunset is approximated in each of Figures 1 through 4 by the curved line designated as the Sun-Earth line.) Figure 9 illustrates this nocturnal increase for the year 1958. It should be noted that for Tucuman, Argentina, there was no nocturnal increase in electron density during the months of July and December, and likewise there was none for Bogota, Colombia, during the month of August. Some significance may be attached to the fact that the zenith angle of the sun is generally least at the geodetic equator during the months of maximum nocturnal increase (Figure 9). Preliminary analysis of height contour maps similar to Figures 1 through 4, reveal nocturnal height increases coincident with the area between the points of nocturnal electron density buildup.

SECTION III: PRESENTATION & DISCUSSION OF DATA

The number of electrons present at any point in the ionosphere is considered to be proportional to the square of the frequency of the radio wave reflected from this point by the equation (Ref. 2)

$$N = kf^2$$

As a result we may surmise that the frequency itself is not significantly altered by the other characteristics of this medium except in the extent to which these characteristics affect the actual number of electrons present.

The basic ionospheric equation (Ref. 3) for the time rate of change in electron density is

$$\frac{\partial N}{\partial t} = q - L - \mathrm{div}\,(N\vec{v})$$

where, per unit volume, N, q, L, and $(N\vec{v})$ are the number of free electrons, the rate of increase of N due to ionization, the rate of decrease of N due to recombination or attachment, and the vector sum of the N velocities, respectively.

The first term, q, in the basic ionospheric equation depends mostly on three factors which are: (1) The number of particles per unit volume which are susceptible to ionization by ultraviolet irradiation, (2) their spectral susceptibility, and (3) the intensity of the ionizing ultraviolet spectral components of the irradiation. The third factor is affected by: (1) The zenith angle of the sun (because of absorption along the optical path), (2) the radiative state of the sun with respect to these spectral components (because it is considerably dependent on the solar cycle, on solar prominences, sunspots, etc.) and (3) the month of the year (because the minimum to maximum variation of the square of the distance from the sun varies by approximately seven percent). Cosmic ray and Van Allen belt corpuscular radiation influences on the ionization rate in the F_2 region are not expected to be appreciable.

The second term in the continuity equation, the "loss term" L, is considered (Ref. 3) to be: (1) Directly proportional to the square of the number of positive ionized particles per unit volume for recombination, and (2) directly proportional to the first power of N for attachment.

The final term div ($N \vec{v}$) affecting the electron density gradient is the rate of loss of free electrons per unit volume due to their motion. Unless such losses were associated with similar losses of positive charges,an associated potential gradient would result which, if left unchecked, would result in an instability of the ionospheric "layer". Such an instability could conceivably be balanced by some other as yet uncertain mechanism. The effects which would result from thermal expansions and contractions of the gaseous medium as well as those magnetically induced effects have not as yet been fully explored.

SECTION IV: CONCLUDING REMARKS

In general we find that the southern hemisphere does not exhibit as marked variation in electron density as does the northern hemisphere. This may be due to the differences in temperature variations between the southern and northern latitudes and has been assumed to result from the higher albedo ratio in the southern latitudes.

The fact that the nocturnal increase occurs relative to the geomagnetic equator leads to a number of interesting questions. First of all we must determine what relation this has, if any, to the geomagnetic equator and its constituents. Secondly, we would like to know the mechanism which causes this nocturnal buildup e.g., a result of thermal contraction of the medium, effects of the magnetic field, some secondary influence following the solar irradiation, etc. Finally, we should also find why there is a seasonal variation such as the one noticed in Figure 9.

The unusual behavior of the ionosphere in the vicinity of the geomagnetic equator is probably the most important aspect of this report. As may be seen from Figures 5 through 8 there is a reversal in the $\frac{\partial N}{\partial t}$ gradient as one approaches the magnetic equator. This could lead to the conclusion that some factor, as yet not considered, possibly has a controlling effect in this vicinity.

When considering spacecraft systems design, as well as operations, these points become important. The variability of this region of the ionosphere may eventually become as predictable as the weather itself, but we must first learn what parameters are involved, and the amount or type of influence which each contributes toward disturbances in the ionosphere.

The questions which have been left unanswered are presently under study by many investigators. Since more definitive information is required in this environmental area, further study is needed and will be carried out to determine answers to the questions related above.

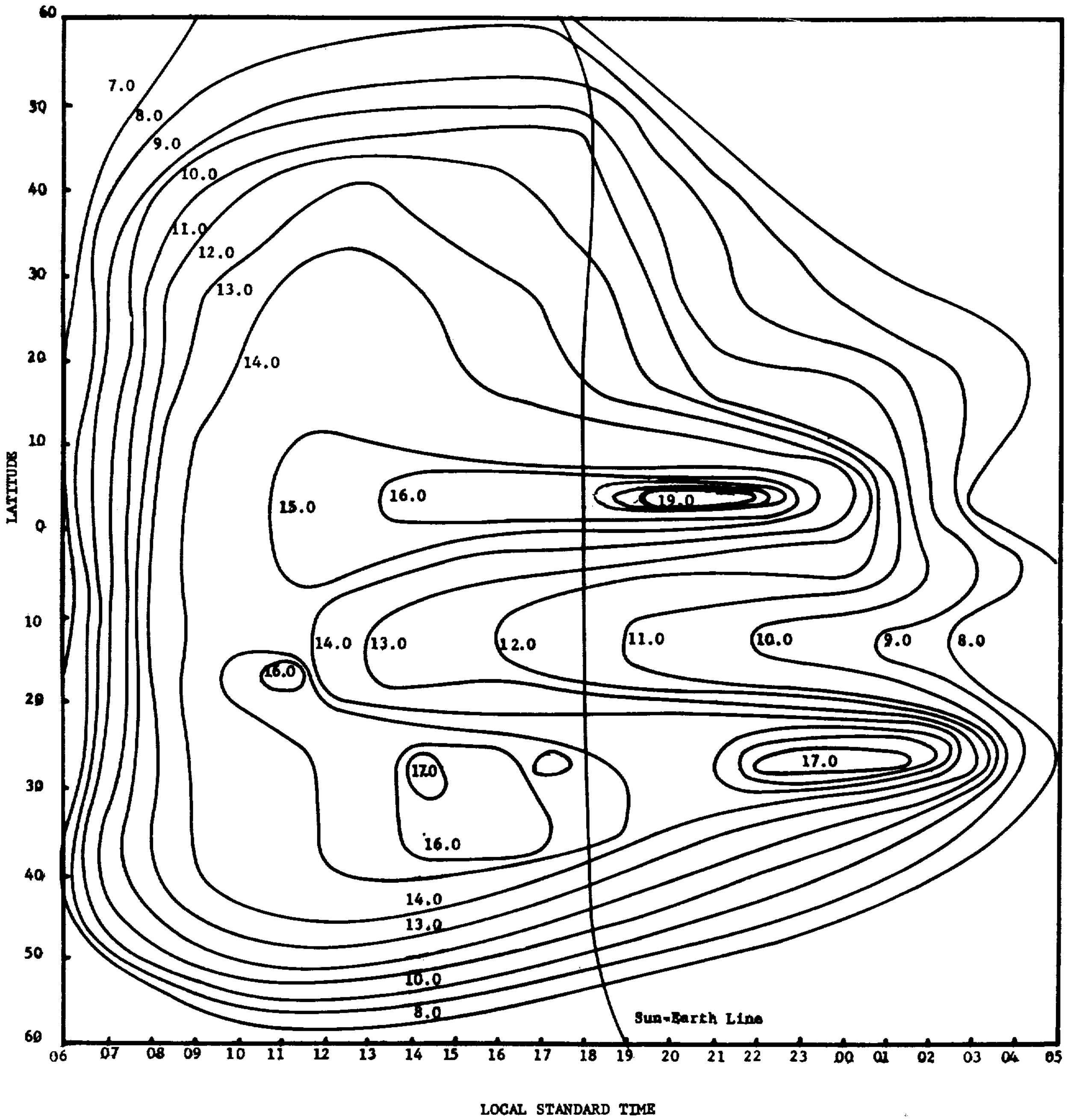

Figure I. Contours of Constant Frequency Averaged Over the Month of March 1958, for Each Hour at Each Station. Contour Frequencies are in Megacycles Per Second.

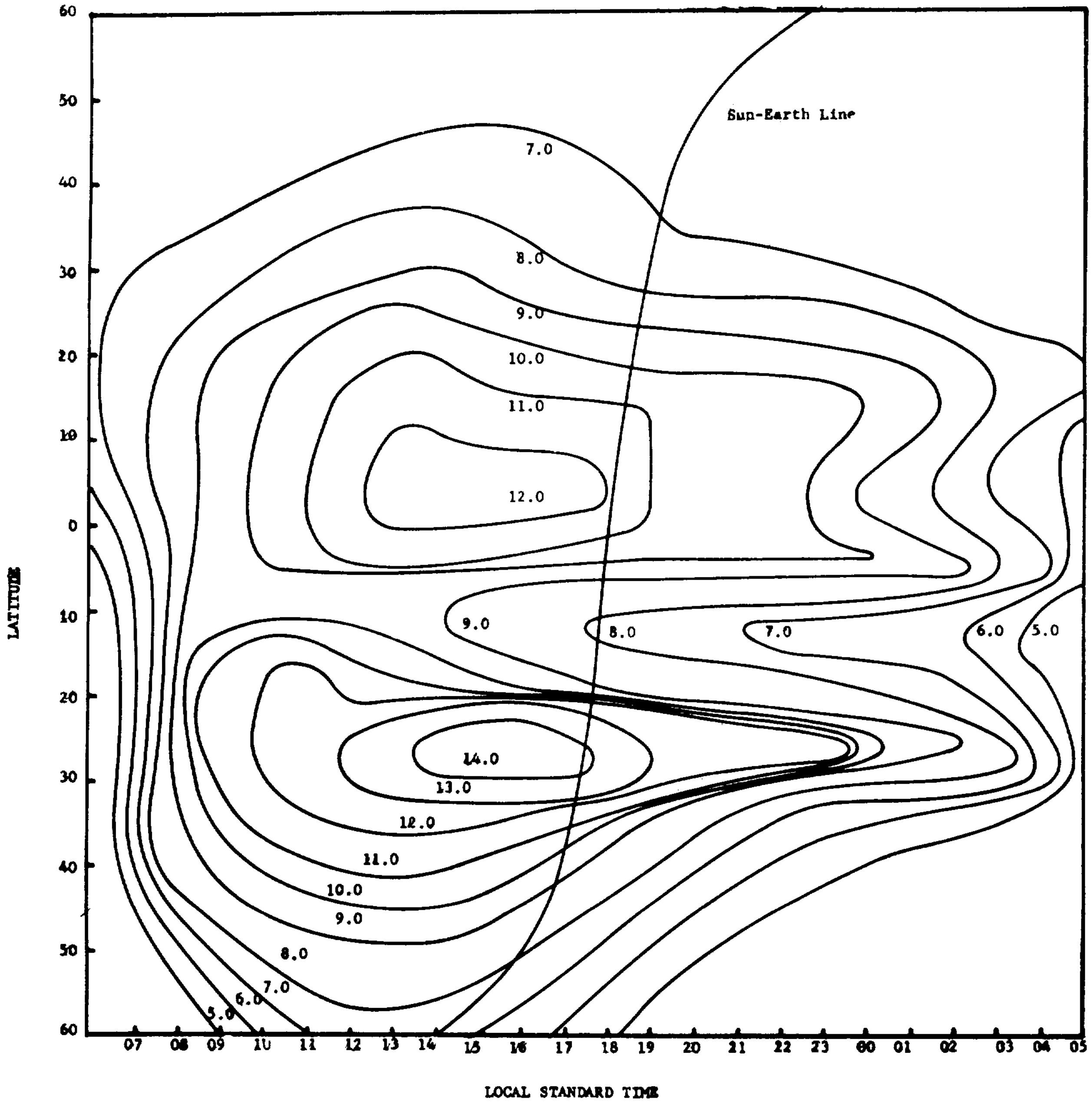

Figure 2 - Contours of Constant Frequency Averaged Over the Month of July, 1958, for Each Hour at Each Station. Contours of Constant Frequency are in Megacycles per Second.

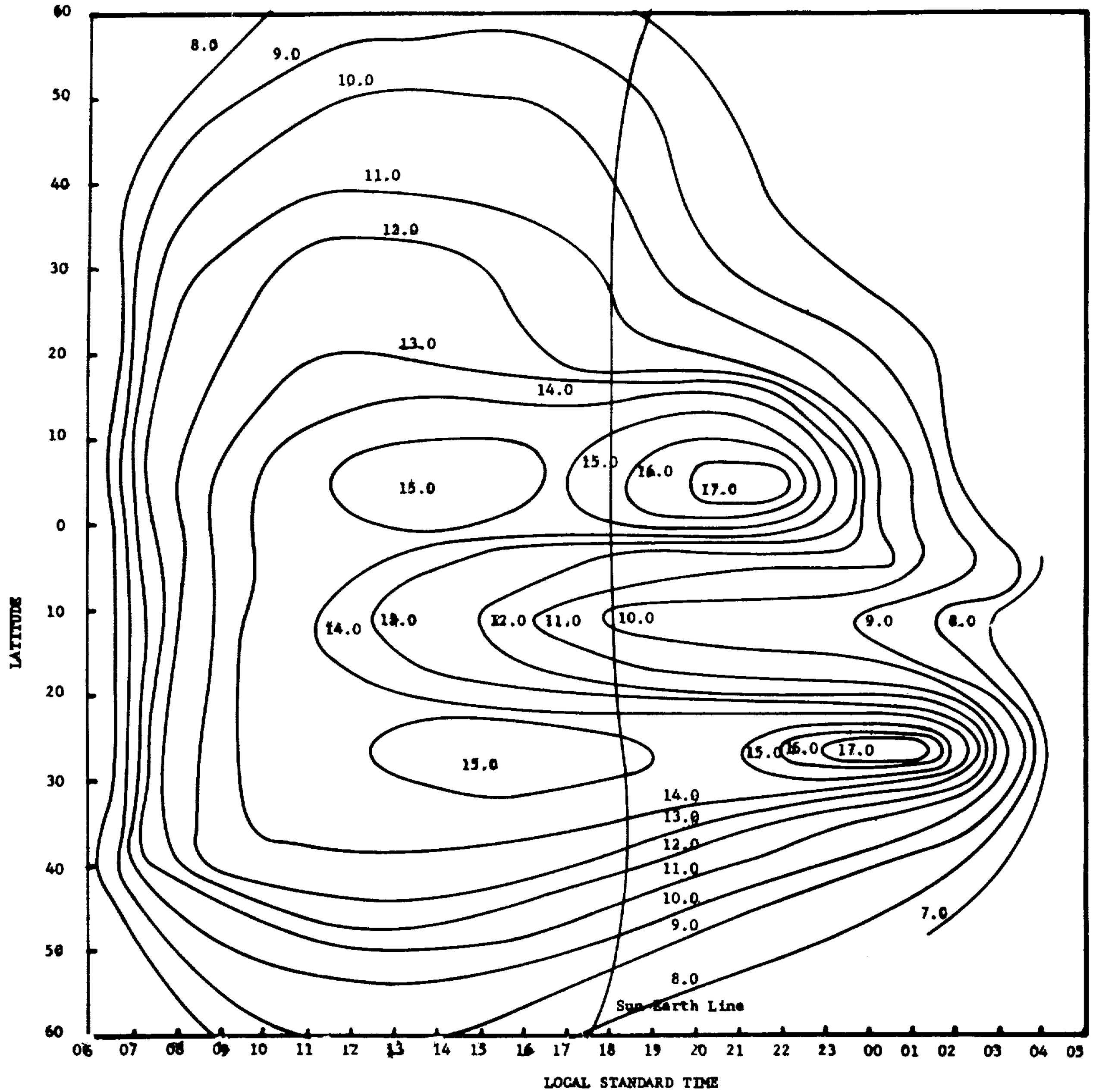

Figure 3 - Contours of Constant Frequency Averaged Over the Month of September, 1958, for Each Hour at Each Station. Contours of Constant Frequency are in Megacycles per Second.

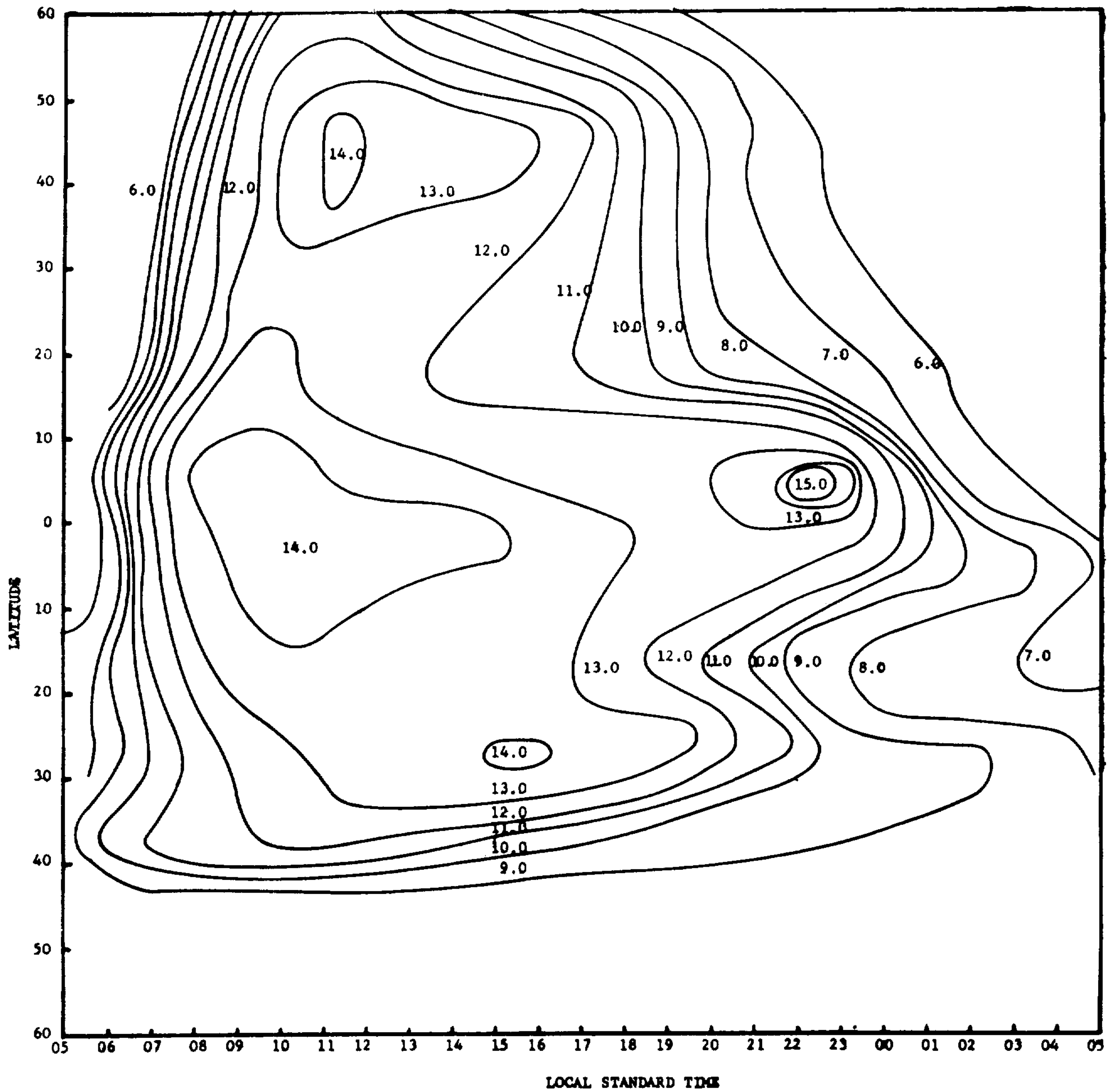

Figure 4 - Contours of Constant Frequency Averaged Over the Month of December, 1958, for Each Hour at Each Station. Contours of Constant Frequency are in Megacycles per Second.

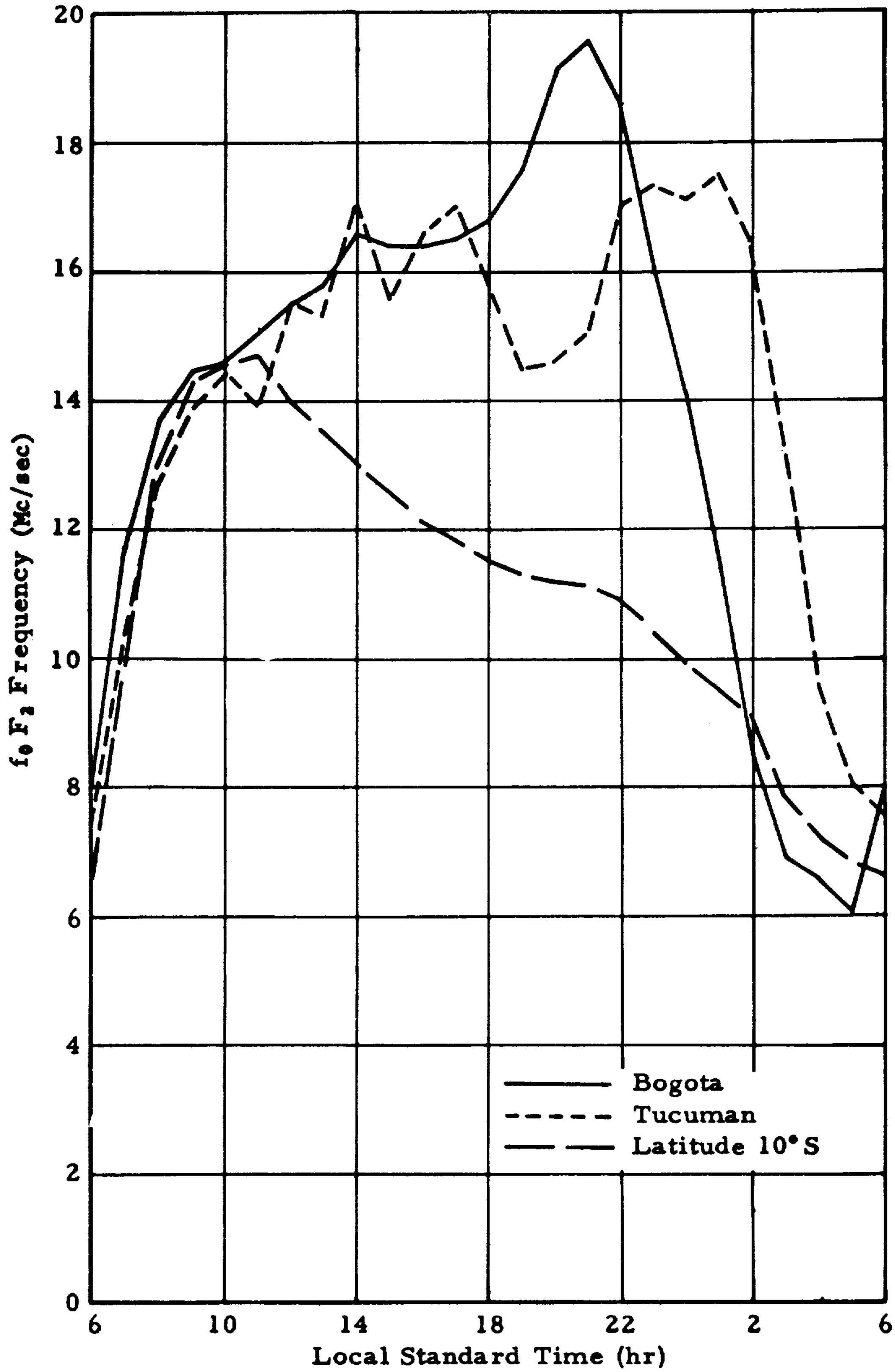

Figure 5. Averaged Value of f_0F_2 at Bogota, Colombia, Tucuman, Argentina, and the Geomagnetic Equator for the Month of March, 1958

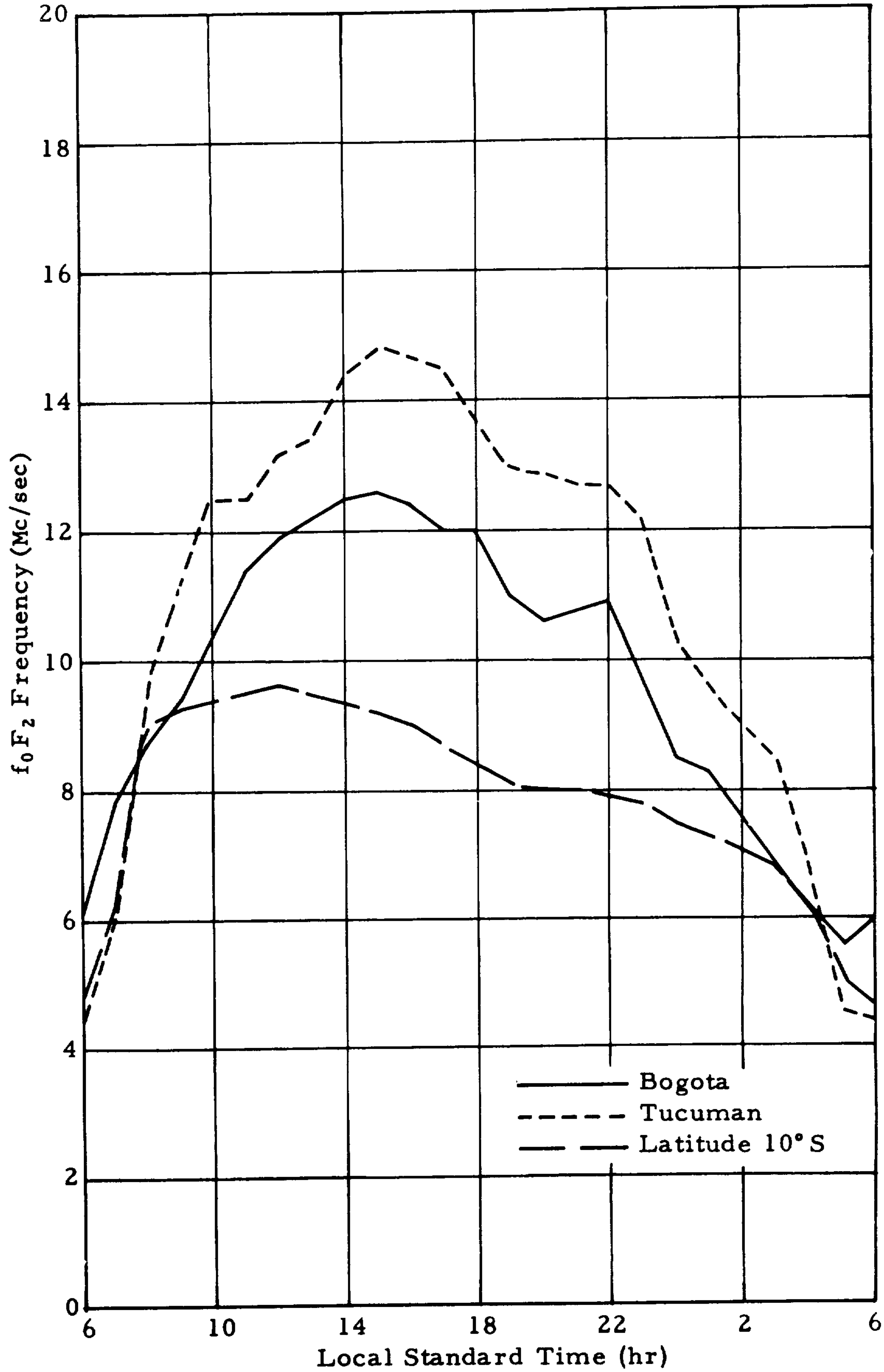

Figure 6. Averaged Value of f_0F_2 at Bogota, Colombia, Tucuman, Argentina, and the Geomagnetic Equator for the Month of July, 1958

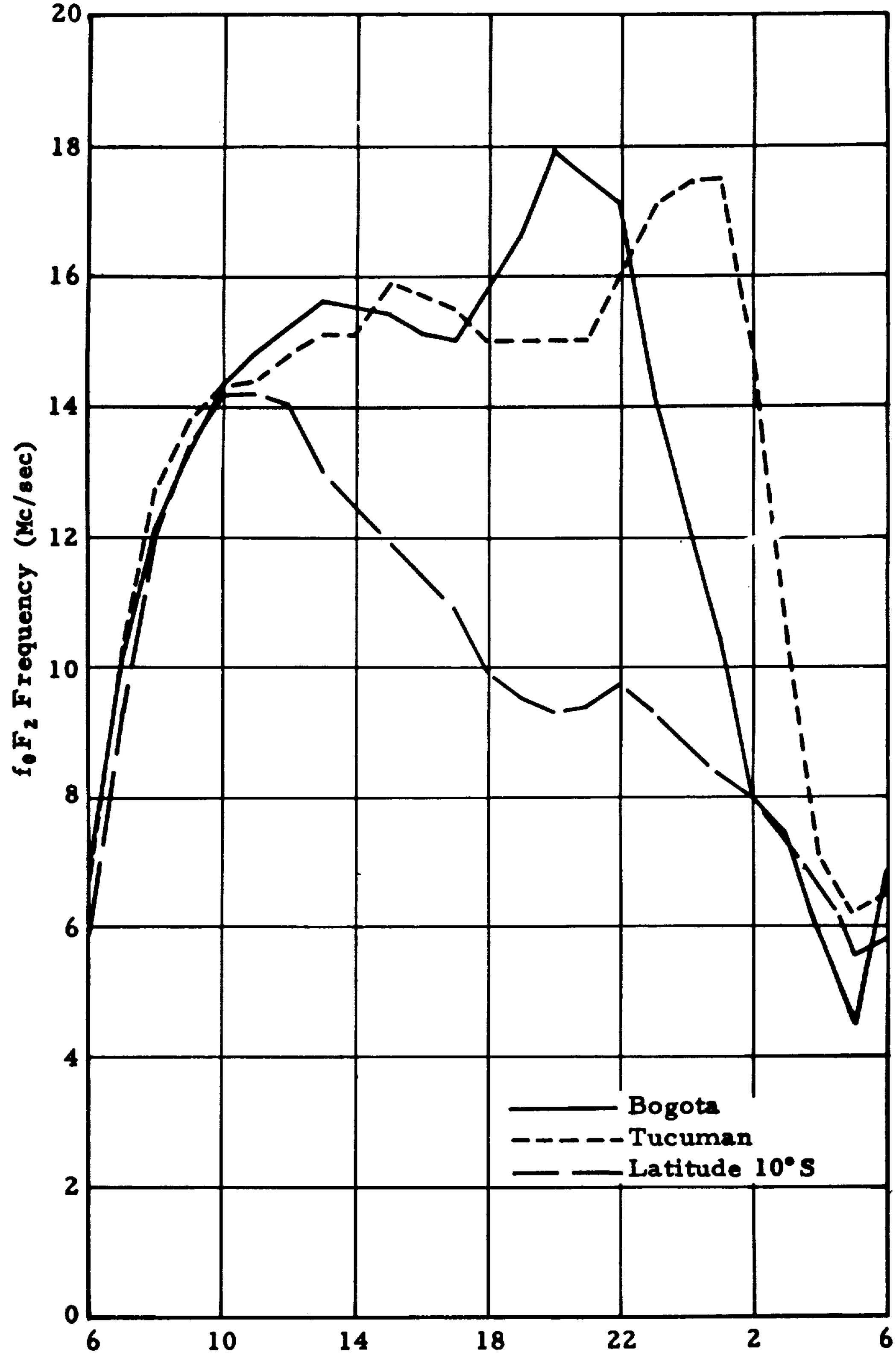

Figure 7. Averaged Value of f_0F_2 at Bogota, Colombia, Tucuman, Argentina, and the Geomagnetic Equator for the Month of September, 1958

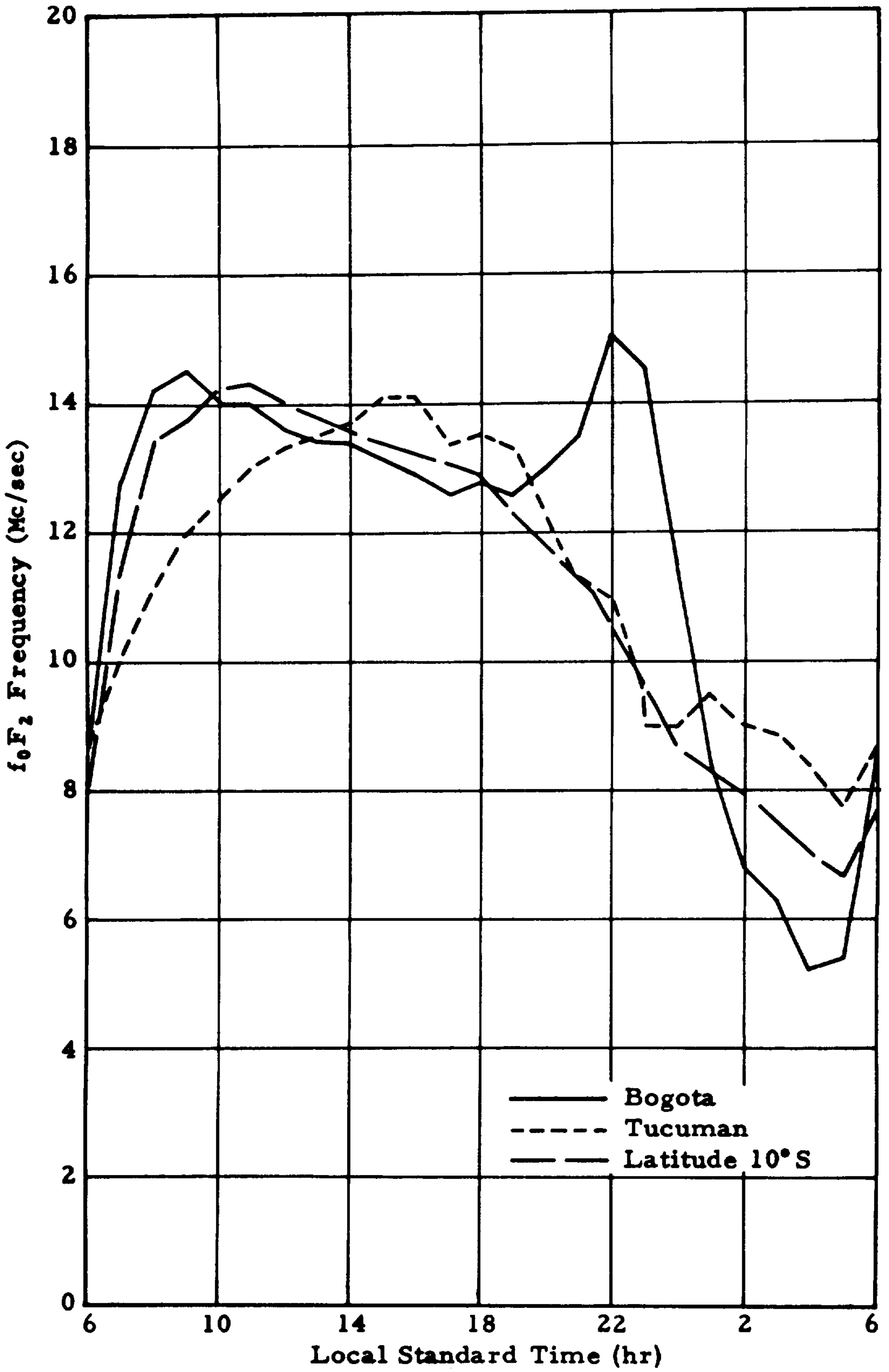

Figure 8. Averaged Value of f_0F_2 at Bogota, Colombia, Tucuman, Argentina, and the Geomagnetic Equator for the Month of December, 1958

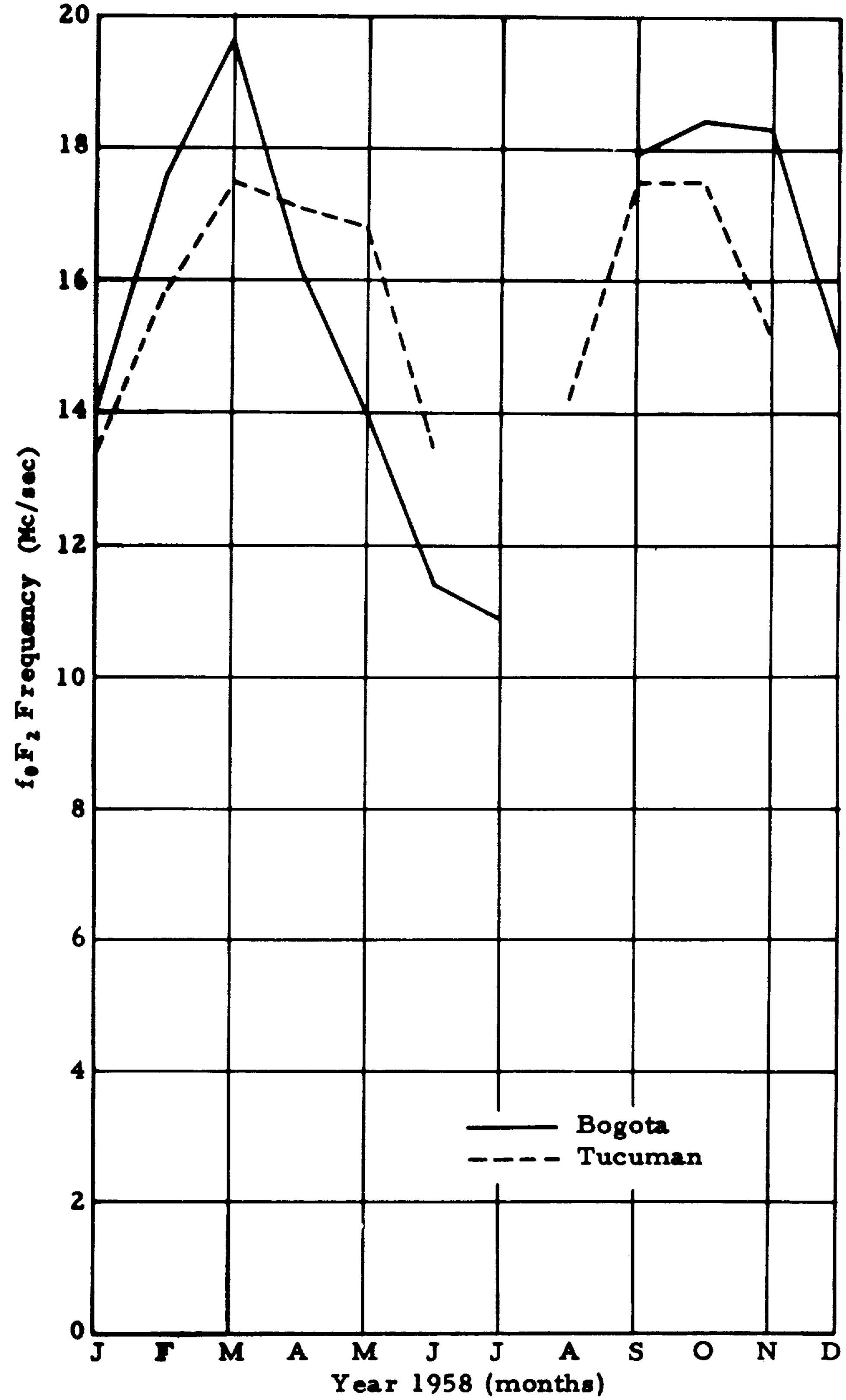

Figure 9. Nighttime Peaks in Electron Densities for Each Month of the Year 1958

Latitudes and Longitudes of Stations Used in the Construction of Contour Maps of Figure 1 Through Figure 4.

TABLE I

STATION	LATITUDE	LONGITUDE
BOGOTA	4°32'N	74°15'W
CAPE CANAVERAL	28°24'N	80°36'W
CHICLAYO	6°48'S	79°49'W
CLYDE	70°27'N	68°33'W
CONCEPCION	36°35'S	72°59'W
FROBISHER	63°45'N	68°34'W
EUREKA	80°00'N	85°56'W
OTTAWA	45°24'N	75°54'W
La PAZ	16°29'S	68°03'W
POLE STATION	90°00'S	-------
TALARA	4°34'S	81°15'W
WASHINGTON	38°44'N	77°08'W
PUERTO RICO	18°30'N	67°10'W
THULE	76°33'N	68°50'W
TRELEW	43°14'S	65°19'W
TUCUMAN	26°53'S	65°23'W
USHUAIA	54°48'S	68°19'W

SECTION V: REFERENCES

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APPROVAL

PROPERTIES OF THE F_2 REGION OF THE IONOSPHERE

The information in this report has been reviewed for security classification. Review of any information concerning Department of Defense or Atomic Energy Commission programs has been made by the MSFC Security Classification Officer. This report, in its entirety, has been determined to be unclassified.

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